National Aeronautics and Space Administration

Microarray Workshop 2007

Advancing Microarray Technology for Space Applications

Jacobs Conference Center
Huntsville, AL

September 27-28, 2007

Sponsored by the Marshall Space Flight Center
Lab-on-a-Chip Application Development (LOCAD) Team

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Workshop Summary

The *NASA Microarray Workshop 2007* was held September 27-28 at the Jacobs Conference Center in Huntsville, AL. During the Thursday morning session, the attendees were given a comprehensive overview of the capabilities of currently available and prototype technologies developed by the NASA MSFC Lab-on-a-Chip Applications Development (LOCAD) team and its collaborators, Charles River Laboratories and Carnegie Institution for Science. Descriptions of LOCAD technology readiness, field testing, and data provided by specific LOCAD devices generated significant dialogue and interest among workshop participants. Extensive discussions identified LOCAD sample preparation and data analysis as high priority areas for future research and development. Additional presentations during the morning session demonstrated the potential benefits of integrating microfluidic and microarray technologies into the next generation of handheld devices. The speakers clearly elaborated the steps that the LOCAD team and collaborators are taking to visualize that goal.

In the Thursday afternoon session, invited speakers described several exciting new techniques ranging from the use of quantum dot aptamers for pathogen identification to polymerase chain reaction (PCR) and electrophoresis on a microfluidic chip. Recent advances in the field of microfluidics were presented and discussed. Scheduled workshop breaks and an on-site lunch allowed for stimulating exchanges and collaborative discussions.

The Friday morning session provided workshop participants with an experienced NASA flight surgeon's overview of the numerous medical challenges awaiting the development and deployment of new technology, followed by a detailed presentation outlining the results obtained to date for environmental monitoring of microbes on the International Space Station. The workshop concluded with an invited presentation from the Chief Medical Office at NASA Headquarters, which provided a description of NASA's current crew health policy. The discussion session that followed highlighted potential areas of revision to the standing policies.

In conclusion, the workshop successfully accomplished its goal of providing a scientific and technical forum to explore microarray and microfluidic technologies for space and terrestrial applications. An appropriate mix of attendees from government agencies, private corporations, and academic institutions each brought a unique element to the discussions. The participants agreed that the workshop had fulfilled its objectives, providing a unique forum for interdisciplinary discussion and an engaging exchange of ideas. A follow-up meeting with more targeted break-out sessions and focus groups is currently being planned, the results of which will be used to better inform new policies on the application of related biomedical technologies.

Workshop Goal

Provide a scientific and technical forum to explore microarray and microfluidic technologies for space and terrestrial applications.

Overall Objectives

I. Describe the capabilities of the LOCAD-PTS and extended PTS systems

- **a. Identify which areas of research and technology development in academic, industry, and government settings will be further enabled by LOCAD-PTS technology**
- **b. Explain the integration of microfluidics and microarray analysis into the LOCAD-PTS**

II. Explore microarray and microfluidic techniques that will advance space and terrestrial applications

III. Identify collaborative efforts

Agenda

Thursday, September 27, 2007

8:30 am – 9:00 am	Bagels and Coffee
9:00 am – 12:15 pm	**Session I: Microarrays and the Future of LOCAD**
9:00 am – 9:15 am	**Mark Boudreaux**, NASA Marshall Space Flight Center Welcome and Introduction
9:15 am – 9:30 am	**Lisa Monaco**, Jacobs ESTS Group "Origins and Milestones: an Overview of LOCAD Technology Development"
9:30 am – 10:00 am	**Norm Wainwright**, Director, R&D, Charles River Laboratories "Testing the LOCAD-PTS on the International Space Station"
10:00 am – 10:10 am	Discussion
10:10 am – 10:40 am	**Andrew Steele**, Professor, Carnegie Institution of Washington "Arctic Testing of an Expanded-Capabilities PTS: Applications for Life Detection and Planetary Protection"
10:40 am – 10:45 am	Discussion
10:45 am	Morning Break
11:00 am – 12:00 pm	**Discussion: "Technologies and Agencies Most Enabled by LOCAD"**
12:00 pm	Break for Lunch
1:30 pm – 5:00 pm	**Session II: Microarray and Lab-on-a-Chip Techniques for Space/Terrestrial Applications** Discussion Leader: **Andrew Steele**, Carnegie Institution
1:30 pm – 2:00 pm	**Johnathan Kiel**, Principal Investigator, Air Force Research Laboratory "Select Agent Recovery and Identification Using Aptamer-Linked Immobilized Sorbent Assay"
2:00 pm – 2:10 pm	Discussion
2:10 pm – 2:40 pm	**Stephen Johnston**, Director, Center for Innovations in Medicine, Arizona State University "Presymptomatic Diagnosis of Health Status: A Convergence of Need and Opportunity"
2:40 pm – 2:50 pm	Discussion
2:50 pm – 3:45 pm	**Discussion: "Latest Advances in the Fields of Arrays and Chips"**
3:45 pm	Afternoon Break
4:00 pm – 4:30 pm	**James Landers**, Professor, University of Virginia "Microfluidic Devices for Ultrafast Genetic Analysis with Sample In / Answer Out Capability: Where to from here?"
4:30 pm – 4:40 pm	Discussion
4:40 pm – 5:10 pm	**David Danley**, Director, Homeland Security and Defense Programs. CombiMatrix Corp. "Application of a Semiconductor-based Microarray to the Detection of Nucleic Acids, Proteins, and Small Molecules using Electrochemical Detection"

5:10 pm – 5:20 pm	Discussion
5:30 pm – 6:30 pm	*Social Hour* *Dinner on your own*

Friday, September 28, 2007

8:30 am – 9:00 am	Breakfast
9:00 am – 12:30 pm	**Session III: The Future of Microarrays in Space/Terrestrial Technology Applications**
	Discussion Leader: **Norman Wainwright**, Charles River Laboratories
9:00 am – 9:30 am	**Jeff Jones**, Flight Surgeon, NASA JSC "Title TBA"
9:40 am – 9:50 am	Discussion
9:50 am – 10:20 am	**Mark Ott**, Microbiology Laboratory, Johnson Space Center "Microbiological Monitoring for the Constellation Program: Current Requirements and Future Considerations"
10:20 am – 10:30 am	Discussion
10:30 am	Morning Break
10:40 am – 11:10 am	**John Allen**, Manager, Space Medicine Policy and Oversight, NASA HQ "Informing NASA Medical Policy"
11:10 am – 11:20 am	Discussion
11:20 am – 12:20 pm	Discussion: "Challenges for Space Technology Applications"
12:20 pm – 12:30 pm	**LOCAD Team – Closing Remarks**

Abstracts

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Select Agent Recovery and Identification Using Aptamer-Linked Immobilized Sorbent Assay

Environmental recovery and identification technology for Select Agents (potential biological warfare or terrorism agents) requires the capability of a flexible and rapid response, whose rapidity and flexibility exceed the current capability of immunodiagnostic assays. These new assays also need to be brought as far forward in the “Area of Responsibility” as possible to facilitate the appropriate sequestration of exposed areas, handling of exposed individuals and expected casualties. Therefore, any such new assays must be extremely robust and require a minimal logistic tail. We will present a field example of such a new technology, Aptamer-Linked Immobilized Sorbent Assay (ALISA), that was used in Houston, Texas, to address a recent tularemia alarm of Biowatch and its comparison to a number of standard assays. We will also present formats for this assay that go further to meet the robustness requirement than the standard ELISA-like format.

Key Words: Aptamers, tularemia, bioterrorism, identification

James P. Landers
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Microfluidic Devices for Ultrafast Genetic Analysis with Sample-In / Answer-Out Capability: Where to from here?

A Microfluidic Genetic Analysis (MGA) system capable of genetic analysis with sample-in/answer-out capabilities must be able to accept real-world samples, execute multiple, sequential sample preparation steps, and then provide an interpretable read-out following separation and detection. These processes involve chromatographic separation of sample components for isolation of DNA, the enzyme-mediated amplification of target DNA sequences in a temperature-dependent manner, the electrophoretic separation of the products of amplification, and detection by fluorescence. In order to accomplish the tasks within the nanospace of the microfluidic architecture, there has to be exquisite fluidic nanoliter volume control. This is accomplished using nothing more than a single nanoliter-flow syringe pump, a series of elastomeric valves, and restrictive flow built into the microchannel architecture which, collectively, allow for precise control of fluid flow through the sample preparation domains and into the separation domain. The effectiveness of the MGA system for the detection of select infectious disease agents (B. Pertussis; B. Anthracis) from multiple sample types (nasal swab, blood, nasal aspirate) in microliter (and sub-microliter) volume samples has been shown. In addition, the potential for interrogation of human genomic DNA for mutations associated with the diagnosis of T-cell lymphoma will be discussed. Together these represent a microchip capable of sample-in/answer-out analysis - a bona fide micro-total analysis system – and a technology ripe for translation in the clinical medicine sector. However, much work remains to be done with respect to simple valving solutions for accurate fluidic control, minimizing the external hardware for packaging into a portable system and improved detection.

David L. Danley, Ph.D.
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Application of a Semiconductor-based Microarray to the Detection of Nucleic Acids, Proteins and Small Molecules using Electrochemical Detection

CombiMatrix has developed a semiconductor-based microarray with 12,544 electrodes, CMOS circuitry, and software to control voltage and current at each electrode. This array was initially commercialized as a custom gene chip for fluorescence detection of nucleic acid hybridization. Fortunately, DNA synthesis on the array does not damage the CMOS circuitry, and it can be used to measure hybridization electrochemically using a redox enzyme and soluble reagents to create a current. In comparative studies, electrochemical detection (ECD) showed very good correlation with fluorescence detection but with better sensitivity. In addition, by eliminating optical scanning, ECD readers can be small and rugged and eliminate confounding issues, such as, focusing, alignment, and large data files. However, the true capabilities of the microarray reside in the fact that it is a highly multiplexed transducer that converts energy from one form (e.g., electrical signal) into another (e.g., chemical reaction). As a sensor, its functions are defined by the molecules deposited on its surface and the method used for ECD. For capturing proteins and small molecules, specific antibodies can be deposited on individual electrodes or high binding DNA aptamers can be created using an iterative evolutionary process. For ECD, methods requiring fewer reagents are being investigated, including, cyclic voltammetry and other more exotic methods of detection.

John R. Allen, Ph.D.
Manager, Space Medicine Policy and Oversight
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Informing NASA Medical Policy

Space exploration has resulted in countless technologies that have benefited both space related activities as well as the broader pubic. The need for these technologies is driven by policies and standards that are set at the highest levels of NASA. The Office of the Chief Health and Medical Officer is responsible for the development of policies and standards that drive deliverables with the goal of improving and maintaining the health of the astronaut corps. The Space Flight Human System Standards and NASA Standard 3000 (standards) are key to this purpose. Technologies are required to both conduct research to inform the development of these standards and to produce deliverables to then meet the standards.

The research and development of countermeasures and technologies for the protection of the health, well being, and safety of exploration crews are then conducted based on these policies and Standards by the appropriate NASA organizations. Countermeasure and technology research is led by the Exploration Systems Mission Directorate's Advanced Capabilities Division and the ESMD Program Project at the Johnson Space Center, Human Research Program.

The significance of these standards and how technologies, such as microarray sensor systems, inform space medicine policies and standards will be discussed.

Stephen Albert Johnston
Center for Innovations in Medicine, the Biodesign Institute, Arizona State University

Presymptomatic Diagnosis of Health Status: A Convergence of Need and Opportunity

The value of being able to monitor health status on space missions is clear. This capability should be comprehensive and near realtime. Interestingly, these are exactly the same requirements for defense against biological attack. Yet, the investment needed to meet these requirements is probably not sustainable based on the rationale of these areas alone. "Fortunately" for NASA and DHS, the impetus to develop presymptomatic diagnostic technology will be driven by the health care crisis. The current system is not sustainable. Either the healthcare provided is reduced or there is a revolution in medicine to treatment presymptomatically versus post symptoms. I will outline some basic requirements for making this revolution and briefly discuss some of our efforts to build synthetic antibodies as part of this initiative.

C. Mark Ott, PhD

Microbiological Monitoring for the Constellation Program: Current Requirements and Future Considerations

Microbiological requirements for spaceflight are based on assessments of infectious disease risk which could impact crew health or mission success. The determination of risk from infectious disease is composed of several factors including (1) crew susceptibility, (2) crew exposure to the infectious disease agent, (3) the concentration of the infectious agent, and (4) the characteristics of the infectious agent. As a result of the Health Stabilization Program, stringent monitoring, and cleaning protocols, in-flight environmental microbial monitoring is not necessary for short-duration spaceflights. However, risk factors change for long-duration missions, as exemplified by the presence of medically significant organisms in the environments of both the Mir and International Space Station (ISS). Based upon this historical evidence, requirements for short duration usage aboard the Orion Crew Exploration Vehicle and Lunar Lander Vehicle will not require in-flight monitoring; however, as mission duration increases with a Lunar Outpost, an ability to detect microbial hazard will be necessary. The nature of the detection requirements will depend on the maturity of technology in a rapidly evolving marketplace. Regardless, the hardware will still need to maximize information to discipline experts and the crew, while minimizing the size, mass, power consumption, and crew time usage. The refinement of these monitors will be a major goal in our efforts to travel successfully to Mars.